MOISTURE AND DENSITY - MAD

Introduction

Moisture content and mineral density (MAD) are basic physical properties that are determined most accurately through mass and volume determinations. The results of MAD measurements provide a direct estimate of porosity, void ratio and the average density of the samples. Porosity variations are controlled by consolidation and lithification, composition, alteration, and deformation of the rocks or sediments. The physical properties can be used with other types of data to study processes in the ocean crust, e.g., fluid migration studies, or analysis of seismic survey data.

The MAD dataset, sometimes called Index Properties, is one of the most complete sets of data collected by the Ocean Drilling Program (ODP). Over 92,000 samples were taken from cores recovered on 105 of the 110 ODP Legs. MAD properties have been determined from samples starting on the first leg of the Deep Sea Drilling Program (DSDP) as described by Boyce, 1973. Although the method for calculating the MAD properties has changed some since the beginning of the DSDP, these data still represent a significant data set. During ODP, MAD properties were calculated using wet and dry mass measurements taken with electronic balances, and wet and dry volume measurements taken with helium displacement pycnometers. The properties that were calculated from these data are: wet bulk density, dry bulk density, grain density, water content (bulk), water content (dry), percent porosity and void ratio.

Data Acquisition

Mass and volume measurements were needed in order to calculate the MAD properties. Four different methods of calculating the physical properties were used during the ODP. Methods A, B, and C assumed the sample was saturated – all pore spaces filled with water; Method D was developed to analyze unsaturated samples. Over the course of the program, Method C was determined to more accurately estimate the MAD properties for saturated samples. A comprehensive discussion of the methods and calculations can be found in *Technical Note 26: Physical Properties Handbook*, Chapter 2.

Mass measurements were made using two high-precision electronic balances. The ship environment with constant motion and cyclically changing gravity made mass determinations more difficult. The two-balance system allowed a reference mass to be used at the same time as the unknown sample mass in order to get as accurate a measurement as possible.

Volume measurements were made using the Quantachrome Corporation Penta-Pycnometer. The pycnometer works on the principle that a sample displaces an amount of fluid equal to its volume. The Quantachrome pycnometer used helium. The Quantachrome had 5 measurement cells; usually a sphere standard was run with four unknowns to provide a control measurement. The standard was moved through the cells to check the drift. When the drift was greater than 0.02 cm^3, the cell had to be recalibrated.

Different methods of removing water from the samples were used. Freeze-drying and heating in a microwave had been used, but the most common method was drying samples in a convection oven at temperatures between 100 ^{O}C and 110 ^{O}C for 24 hours.

Changes in MAD data acquisition procedures were due to improvements in the data acquisition software. The first programs were written in BASIC and required quite a bit of operator entry. The data acquisition program used at the end of the ODP required little manual entry from the operator and mostly automated the procedures for data collection.

Standard Operating Procedures

Core samples of approximately 8 cm^3 were collected from the working half after the sections had been split. Two samples per section were usually taken for physical properties determination, but sampling density was highly variable depending on core recovery or the scientific requirements of the Shipboard Scientific Party.

The samples were put into calibrated beakers for analyses. The beakers had been previously measured to determine mass and volume. Sample mass and volume measurements were dependent on the method that would be used to calculate the properties. Wet samples were weighed; for much of the ODP, volume measurements were also taken on the wet samples. The samples were then dried for 24 hours at temperatures between 100 ^{O}C and 110 ^{O}C in a convection oven. Drying was intended to remove the interstitial water and was the most critical part of the procedure. Using this method to dry samples may have also removed a substantial portion of the interlayer water from clays, so samples with high clay content could have errors of up to 20% in the calculated porosity. After drying, the samples were weighed again, and the volume determined using the helium pycnometer.

Calibrations

Both the balances and the pycnometer needed to be calibrated periodically. The equipment was usually calibrated at the beginning of each leg, and during the leg if there was a problem. Calibration information was not archived.

Beaker calibrations were also done, though not every leg. Beaker volume was difficult to measure because the low volume to void ratio in the pycnometer cell gave inaccurate values. Instead, a beaker's mass was determined and the volume calculated based on the density of the material. Aluminum beakers (density of 2.78 g/cm^3) were used from Leg 101 until they were replaced with Pyrex beakers (density 2.2 g/cm^3) on Leg 169.

Calculations

Below is a summary of the measured and calculated parameters used to calculate the MAD properties for the four methods used during the ODP. (This table was originally produced by Peter Blum.)

Table 1: Methods of Moisture and Density properties determination

Property	**Formula**	**Method A**	**Method B**	**Method C**	**Method D**
Material		soft, saturated	saturated	saturated	unsaturated
Use recommended		No	No	Yes	Yes
Measurements					
Total Mass, Mt		Mt	Mt	Mt	
Dry Mass, Md		Md	Md	Md	Md
Total Volume, Vt		Vt (fixed)	Vt (pycnometer)		Vt (geometry)
Dry volume, Vd				Vd (pycnometer)	Vd (pycnometer)
Method-specific calculations for Mt, Mpw, Vt, Vpw					
Mpw1 -- mass of pore water (saturated)	(Mt – Md) / (1 - s / 1000)	Mpw1	Mpw1	Mpw1	
Vpw1 -- volume of pore water (saturated)	Mpw1 / Dpw	Vpw1	Vpw1	Vpw1	
Vt – Total volume	Vd – Vsalt + Vpw1			Vt	
Vd – Dry Volume	Vs + Vsalt	Vd	Vd		
Vpw2 -- volume of pore water (unsaturated)	Vw =Vt - Vd				Vpw2
Mpw2 -- mass of pore water (unsaturated)	Mpw2 = Vw * Dpw				Mpw2
Mt -- Total mass	Md + Mw = Md + (Vt – Vd) * Dw				Mt

Properties	**Formula**
Assumptions	
Density of water	Dw =1.000
Density of pore water	Dpw = 1.024
Density of salt	Dsalt = 2.222
Salinity of pore water	s = 35
Additional calculations	
Msalt -- Mass of salt	Mpw – (Mt - Md)
Vsalt -- Volume of salt	Msalt / Dsalt
Ms -- Mass of solids	Md - Msalt
Vs -- Volume of solids	Vd - Vsalt
Moisture and Density Property Calculations	
WW -- Water Content	Mpw / Mt
WD -- Water Content	Mpw / Ms
BD -- Bulk Density	Mt / Vt
DD -- Dry Density	Ms / Vt
GD -- Grain Density	Ms / Vs
PO -- Porosity	Vpw / Vt
VR -- Void ratio	Vpw / Vs

Archive

Pre-Janus Archive

Early in the ODP, MAD data were collected on logsheets which were sent back to ODP/TAMU at the end of each cruise. The data were entered into an S1032 database and the logsheets were microfilmed for archival storage. Data entry routines were implemented so that data entry could be done on the ship and the practice of collecting data on logsheets ended. MAD data were stored in the S1032 database through Leg 149. From Leg 150 – Leg 166, MAD data were stored in a Macintosh 4D database. After Leg 166, data were stored in text files or Excel spreadsheets. All files were archived on ODP/TAMU servers.

Migration of MAD data to Janus

The data model for Moisture and Density data can be found in Appendix I. Included are the relational diagram and the list of the tables that contain data pertinent to MAD analyses, the column names and the definition of each column attribute. ODP Information Services Database Group was responsible for the migration of pre-Leg 171 data to Janus.

One of the difficulties with the migration of MAD data to Janus was the migration of the beakers and their mass and volume data. Most of the data entries recorded the beaker number that was used for each analysis; however, very often the mass and volume of the beaker were not saved in that entry. Beakers were not calibrated on each leg, so it was not always clear which beaker mass and volume file was used during the leg when no beaker file was archived at ODP/TAMU with the leg's MAD data.

Janus Moisture and Density Data Format

MAD analyses can be retrieved from Janus Web using a predefined query. The Moisture and Density query webpage allows the user to extract data using the following variables to restrict the amount of data retrieved: leg, site, hole, core, section, depth, or latitude and longitude ranges. In addition, the MAD query gives the user options to retrieve the raw data, retrieve data for a single method, and filter records based on a range of calculated values of one of the properties, e.g., bulk density, porosity, etc.

Most of the calculated values are not stored in Janus. They are calculated from the raw data when the web query is run. When Janus first started operations, the method used to calculate the MAD properties was determined by which measurements were in the database; the method was not explicitly stored. After the migration of MAD data started, changes to the data model became necessary because some legs were missing raw data, and some beaker mass and volume values were missing. The data model was changed to store calculated values, and a column that explicitly defined the method was added. Samples with missing raw data or beaker information were added to Janus using the calculated values reported in the Initial Reports volumes or calculations from the logsheets.

Table 2 contains the data fields retrieved from the Janus database using the Janus Web predefined query with the Output Raw Data option. The first column contains the data item; the second column indicates the Janus table or tables in which the data were stored; the third column is the Janus column name or the calculations used to produce the value. (Calculations for some of the parameters differ, depending on the method used for analysis. See Table 1.) Appendix II contains additional information about the fields retrieved using the Janus Web Moisture and Density query, and the data format for the archived ASCII files.

Table 2. Moisture and Density query with Output Raw Data option

Item Name	**Janus Table**	**Janus Column Name**
Leg	SECTION	Leg
Site	SECTION	Site
Hole	SECTION	Hole
Core	SECTION	Core
Coretype	SECTION	Core_type
Section	SECTION	Section_number
Top (cm)	SAMPLE	Top_interval x 100
Bottom (cm)	SAMPLE	Bottom_interval x 100
Depth (mbsf)	DEPTH_MAP, SAMPLE	DEPTH_MAP.Map_interval_top + SAMPLE.Top_interval
Water Content (bulk) (%)	MAD_SAMPLE_DATA	Calculated or *Water_content_bulk.*
Water Content (dry) (%)	MAD_SAMPLE_DATA	Calculated or *Water_content_dry*.
Bulk Density (g/cc)	MAD_SAMPLE_DATA	Calculated or *Bulk_density.*
Dry Density (g/cc)	MAD_SAMPLE_DATA	Calculated or *Dry_density.*
Grain Density (g/cc)	MAD_SAMPLE_DATA	Calculated or *Grain_density.*
Porosity (%)	MAD_SAMPLE_DATA	Calculated or *Porosity*.
Void Ratio	MAD_SAMPLE_DATA	Calculated or *Void_ratio*.
Mass(bulk+beaker)(g)	MAD_SAMPLE_DATA	Mass_wet_and_beaker.
Mass(dry+beaker)(g)	MAD_SAMPLE_DATA	Mass_dry_and_beaker..
Vol.(bulk+beaker)(cc)	MAD_SAMPLE_DATA	Vol_wet_and_beaker
stdev(Vol.(bulk+beaker))	MAD_SAMPLE_DATA	Vol_wet_and_beaker_stdev
No of measurements (Vol(bulk+beaker))	MAD_SAMPLE_DATA	Vol_wet_and_beaker_n
cell(Vol.(bulk+beaker)))	MAD_SAMPLE_DATA	Vol_wet_and_beaker_cell.
Vol.(dry+beaker)(cc)	MAD_SAMPLE_DATA	Vol_dry_and_beaker
stdev(Vol.(dry+beaker))	MAD_SAMPLE_DATA	Vol_dry_and_beaker_stdev
No of measurements (Vol.(dry+beaker))	MAD_SAMPLE_DATA	Vol_dry_and_beaker_n
cell(Vol.(dry+beaker))	MAD_SAMPLE_DATA	Vol_dry_and_beaker_cell.
Date/Time	MAD_SAMPLE_DATA	Sample_date_time
Beaker	MAD_SAMPLE_DATA	Mad_beaker_id
Mass beaker (g)	MAD_BEAKER_HISTORY	Beaker_mass
Vol beaker (cc	MAD_BEAKER_HISTORY	Beaker_volume
Mass wet (g)	MAD_SAMPLE_DATA	MAD_SAMPLE_DATA.Mass_wet_and_beaker – MAD_BEAKER_HISTORY.Beaker_mass
Mass dry (g)	MAD_SAMPLE_DATA	MAD_SAMPLE_DATA.Mass_dry_and_beaker – MAD_BEAKER_HISTORY.Beaker_mass
Mass of porewater (g)	MAD_SAMPLE_DATA	Calculated
Mass of Solids (salt corrected) (g)	MAD_SAMPLE_DATA	Calculated
Vol of Porewater (cc)	MAD_SAMPLE_DATA	Calculated
Mass of Evap. Salt (g)	MAD_SAMPLE_DATA	Calculated
Vol. of Evap. Salt (cc)	MAD_SAMPLE_DATA	Calculated
Vol. Bulk (cc)	MAD_SAMPLE_DATA	MAD_SAMPLE_DATA.Vol_wet_and_beaker – MAD_BEAKER_HISTORY.Beaker_volume
Vol. Solids (cc)	MAD_SAMPLE_DATA	Calculated
Vol. Dry (cc)	MAD_SAMPLE_DATA	MAD_SAMPLE_DATA.Vol_dry_and_beaker – MAD_BEAKER_HISTORY.Beaker_volume
Method	MAD_SAMPLE_DATA	Method
Comments	MAD_SAMPLE_DATA	Comments

Data Quality

The MAD dataset is one of the most complete sets of data collected by the Ocean Drilling Program (ODP). There are few known instances where there was a major problem with data collection. The MAD properties values are calculated from the raw data stored in the MAD tables. For this reason it was very important to link the correct beaker information with each analysis record. Verification of the MAD data included: 1) determining the correct beaker mass and volume set that should be associated with each leg; 2) verifying that all samples had been entered; 3) verifying that each analysis record was associated with the correct beaker number and date; 4) verifying that each record was associated with the correct method to be used to calculate the MAD properties.

Much of the data collected before Leg 171 used Method B to calculate bulk density, dry density, porosity, and void ratio, and Method C to calculate grain density. (Bulk water content and dry water content calculations are the same for both Methods B and C.) In many cases, the raw data exist to use both Method B and Method C to calculate the MAD properties. As part of the verification, an additional record was entered so that the MAD properties would be calculated by both methods. Even though the original reports may have published the Method B calculations, the Method C calculations may be better estimates.

There were two common sources of errors found during the migration and verification of the MAD data: missing samples and a generic ‘operator error.’ Missing samples were a common problem – there were no constraints that required a sample record to exist in order to analyze and save data. In those instances, a sample was entered into the database so that the data could be migrated. Anything that was written or typed was subject to ‘operator error.’ Analytical results were written on logsheets. These data were then typed into S1032. Data entry programs were implemented to add the data to S1032, but it still required manual entry. Data acquisition programs were later implemented to collect the raw MAD measurements data, but the operator manually entered the sample information. Writing or typing incorrect information occasionally happened and some mistakes were not identified. Often, the scientific party found errors and corrected them for the data included in the Initial Report volume, but data sent back to ODP/TAMU did not get corrected.

The verification of added samples and verification of the entire MAD properties data set were not completed due to time constraints. Most data collected after the Janus database was operational on Leg 171 were verified as part of the Janus data management and verification procedures (see Metadata Introduction). Some verification was done on the pre-Leg 171 data; however, if there is a discrepancy between the database and data in the Initial Report volumes, the published data should be considered more reliable.

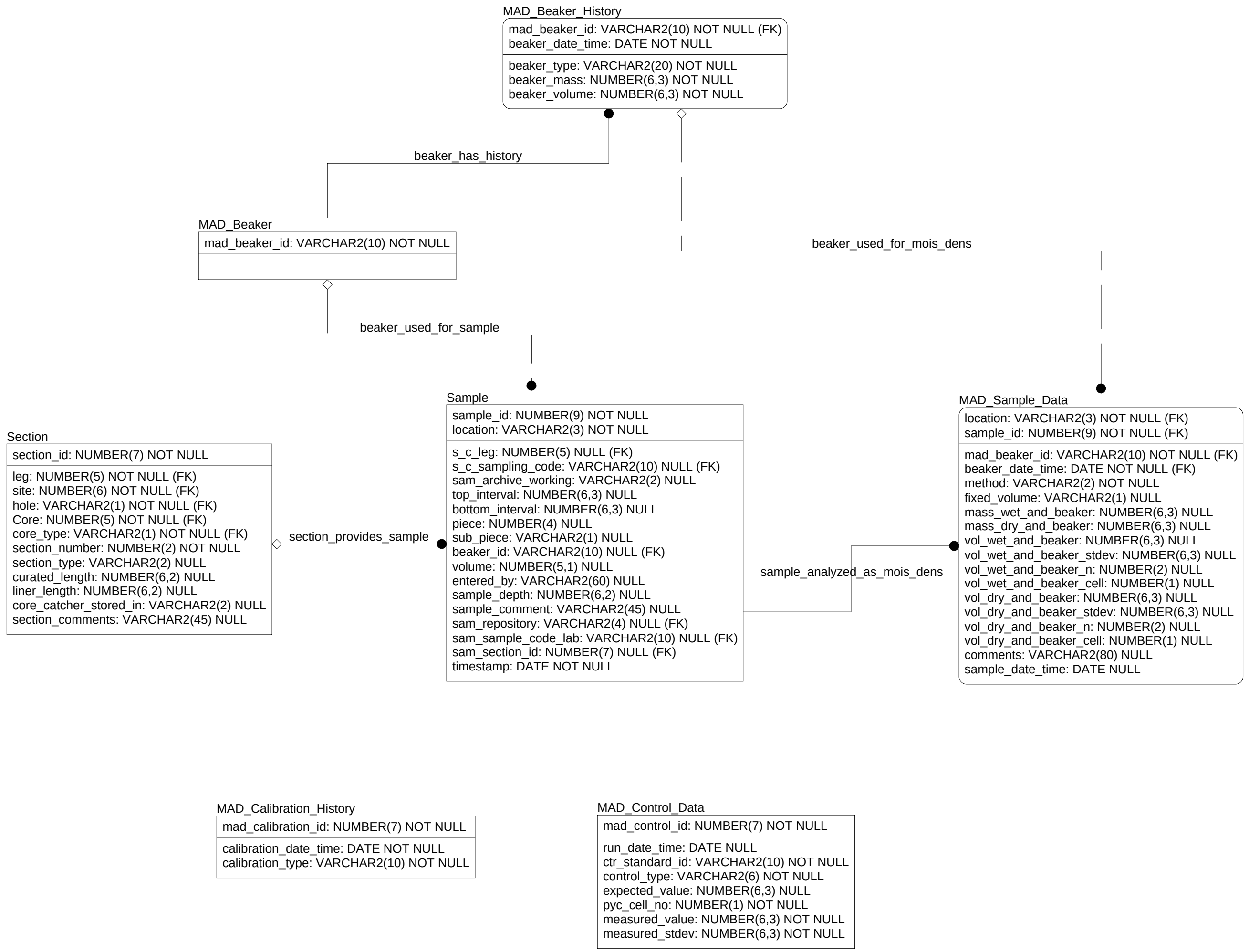
Janus does not contain any calibration information for the MAD instrumentation. Procedures for storing calibration information were not implemented during the ODP.

References

Blum, P., 1997, Physical Properties Handbook: A guide to the shipboard measurement of physical properties of deep-sea cores, ODP Tech. Note 26.

Boyce, R.E., 1973, Appendix I. Physical Properties - Methods. *In* Edgar, N.T., Saunders, J.B., et al., Initial Reports of the Deep Sea Drilling Project, Volume 15: Washington (U.S. Government Printing Office), p. 1115-1128.

Boyce, R.E., 1976, Appendix I. Definitions and Laboratory Techniques of Compressional Sound Velocity Parameters and Wet-Water Content, Wet-Bulk Density, and Porosity Parameters by Gravimetric and Gamma Ray Attenuation Techniques. *In* Schlanger, S.O., Jackson, E.D., et al., Initial Reports of the Deep Sea Drilling Project, Volume 33, p. 931-951.


MAD_Beaker_History
mad_beaker_id: VARCHAR2(10) NOT NULL (FK)
beaker_date_time: DATE NOT NULL
beaker_type: VARCHAR2(20) NOT NULL
beaker_mass: NUMBER(6,3) NOT NULL
beaker_volume: NUMBER(6,3) NOT NULL
beaker_has_history
MAD_Beaker
mad_beaker_id: VARCHAR2(10) NOT NULL
beaker_used_for_mois_dens
beaker_used_for_sample
Sample
sample_id: NUMBER(9) NOT NULL
location: VARCHAR2(3) NOT NULL
s_c_leg: NUMBER(5) NULL (FK)
s_c_sampling_code: VARCHAR2(10) NULL (FK)
sam_archive_working: VARCHAR2(2) NULL
top_interval: NUMBER(6,3) NULL
bottom_interval: NUMBER(6,3) NULL
piece: NUMBER(4) NULL
sub_piece: VARCHAR2(1) NULL
beaker_id: VARCHAR2(10) NULL (FK)
volume: NUMBER(5,1) NULL
entered_by: VARCHAR2(60) NULL
sample_depth: NUMBER(6,2) NULL
sample_comment: VARCHAR2(45) NULL
sam_repository: VARCHAR2(4) NULL (FK)
sam_sample_code_lab: VARCHAR2(10) NULL (FK)
sam_section_id: NUMBER(7) NULL (FK)
timestamp: DATE NOT NULL
MAD_Sample_Data
location: VARCHAR2(3) NOT NULL (FK)
sample_id: NUMBER(9) NOT NULL (FK)
mad_beaker_id: VARCHAR2(10) NOT NULL (FK)
beaker_date_time: DATE NOT NULL (FK)
method: VARCHAR2(2) NOT NULL
fixed_volume: VARCHAR2(1) NULL
mass_wet_and_beaker: NUMBER(6,3) NULL
mass_dry_and_beaker: NUMBER(6,3) NULL
vol_wet_and_beaker: NUMBER(6,3) NULL
vol_wet_and_beaker_stdev: NUMBER(6,3) NULL
vol_wet_and_beaker_n: NUMBER(2) NULL
vol_wet_and_beaker_cell: NUMBER(1) NULL
vol_dry_and_beaker: NUMBER(6,3) NULL
vol_dry_and_beaker_stdev: NUMBER(6,3) NULL
vol_dry_and_beaker_n: NUMBER(2) NULL
vol_dry_and_beaker_cell: NUMBER(1) NULL
comments: VARCHAR2(80) NULL
sample_date_time: DATE NULL
Section
section_id: NUMBER(7) NOT NULL
leg: NUMBER(5) NOT NULL (FK)
site: NUMBER(6) NOT NULL (FK)
hole: VARCHAR2(1) NOT NULL (FK)
Core: NUMBER(5) NOT NULL (FK)
core_type: VARCHAR2(1) NOT NULL (FK)
section_number: NUMBER(2) NOT NULL
section_type: VARCHAR2(2) NULL
curated_length: NUMBER(6,2) NULL
liner_length: NUMBER(6,2) NULL
core_catcher_stored_in: VARCHAR2(2) NULL
section_comments: VARCHAR2(45) NULL
section_provides_sample
sample_analyzed_as_mois_dens
MAD_Calibration_History
mad_calibration_id: NUMBER(7) NOT NULL
calibration_date_time: DATE NOT NULL
calibration_type: VARCHAR2(10) NOT NULL
MAD_Control_Data
mad_control_id: NUMBER(7) NOT NULL
run_date_time: DATE NULL
ctr_standard_id: VARCHAR2(10) NOT NULL
control_type: VARCHAR2(6) NOT NULL
expected_value: NUMBER(6,3) NULL
pyc_cell_no: NUMBER(1) NOT NULL
measured_value: NUMBER(6,3) NOT NULL
measured_stdev: NUMBER(6,3) NOT NULL

APPENDIX I: Janus Data Model – Moisture and Density (MAD)

MOISTURE AND DENSITY - MAD		
Table Name	**Column Name**	**Column Comment**
MAD_Sample_Data	sample_id	Oracle-generated sequence number that with *location* uniquely identifies a sample.
	location	Code that indicates which Janus application assigned the sample_id. Values are SHI(ship), GCR (Gulf Coast Repository), ECR (East Coast Repository, WCR (West Coast Repository) and BRE (Bremen repository). Used with *sample_id* to uniquely identify a sample.
	method	Method used to calculate index properties. Added Mar. 21, 2002. Was made part of the primary key on Feb. 26, 2004.
	mad_beaker_id	Unique ID for beaker used to hold sample.
	beaker_date_time	Time stamp when calibrated beaker mass and volume data entered.
	fixed_volume	Indicates if a fixed volume method was used to determine index properties.
	mass_wet_and_beaker	Mass of the wet sample plus beaker, in grams.
	mass_dry_and_beaker	Mass of the dried sample plus beaker, in grams.
	vol_wet_and_beaker	Volume of the wet sample plus beaker, in cm^3**.**
	vol_wet_and_beaker_stdev	Standard deviation of wet volume measurements.
	vol_wet_and_beaker_n	Number of measurements for wet volume.
	vol_wet_and_beaker_cell	Pycnometer cell number used for the wet volume measurement. Valid values – 1, 2, 3, 4, 5.
	vol_dry_and_beaker	Volume of the dry sample plus beaker, in cm^3.
	vol_dry_and_beaker_stdev	Standard deviation of the dry volume measurements.
	vol_dry_and_beaker_n	Number of dry volume measurements taken, from 1-20.
	vol_dry_and_beaker_cell	Pycnometer cell number used for the dry volume measurement. Valid values – 1, 2, 3, 4, 5.
	comments	General comments
	sample_date_time	Date and time of sample analysis.
	water_content_bulk	Calculated value stored only when raw measurements or valid beaker mass and volume not available. Added Feb. 26, 2004
	water_content_solids	Calculated value stored only when raw measurements or valid beaker mass and volume not available. Added Feb. 26, 2004
	bulk_density	Calculated value stored only when raw measurements or valid beaker mass and volume not available. Added Feb. 26, 2004
	dry_density	Calculated value stored only when raw measurements or valid beaker mass and volume not available. Added Feb. 26, 2004
	grain_density	Calculated value stored only when raw measurements or valid beaker mass and volume not available. Added Feb. 26, 2004
	porosity	Calculated value stored only when raw measurements or valid beaker mass and volume not available. Added Feb. 26, 2004
	void_ratio	Calculated value stored only when raw measurements or valid beaker mass and volume not available. Added Feb. 26, 2004
MAD_Beaker	mad_beaker_id	Unique ID for beaker used to hold sample.
MAD_Beaker_History	mad_beaker_id	Unique ID for beaker used to hold sample.
	beaker_date_time	Calibration date and time of the determination of beaker mass and volume.
	beaker_type	Type of beaker. Pyrex - pyrex 10 ml; Aluminum - aluminum 12 cm^3.
	beaker_mass	Mass of beaker, in grams.
	beaker_volume	Volume of beaker, in cm^3.
MAD_Calibration_ History	mad_calibration_id	Unique Oracle-generated sequence number for a MAD system calibration.
	calibration_date_time	Time stamp when calibration was done - supplied by instrument data files.
	calibration_type	The type of calibration, for example: B – Balance, P - Pycnometer.
MAD_Control_Data	mad_control_id	Unique Oracle-generated sequence number of MAD control run.
	run_date_time	Date and time of a control run.
	ctr_standard_id	Control standard identifier, e.g., sphere7.069 cm^3

MOISTURE AND DENSITY - MAD		
Table Name	**Column Name**	**Column Comment**
	control_type	Mass or Volume
	expected_value	Known value of a control standard, in grams or cm^3 "
	pyc_cell_no	Pycnometer cell number used for the control measurement. Valid values – 1, 2, 3, 4, 5.
	measured_value	The value measured for a standard, in grams or cm^3.
	measured_stdev	Standard deviation for a standard value.

Section	section_id	Unique Oracle-generated sequence number to identify each section. This is done because of the physical subsection / zero section problems. In adding new sections, deleting sections or changing sections - don't want to have to renumber.
	leg	Number identifying the cruise for which data were entered into the database.
	site	Number identifying the site from which the core was retrieved. A site is the position of a beacon around which holes are drilled.
	hole	Letter identifying the hole at a site from which a core was retrieved or data were collected.
	core	Sequential numbers identifying the cores retrieved from a particular hole. Cores are generally 9.5 meters in length, and are numbered serially from the top of the hole downward.
	core_type	A letter code identifying the drill bit/coring method used to retrieve the core. The coretype is only reported in the post-leg 113 processed data file.
	section_number	Cores are cut into 1.5 m sections. Sections are numbered serially, with Section 1 at the top of the core.
	section_type	Used to differentiate sections of core (S) from core catchers (C). Previously core catchers were stored as section CC, but in Janus core catchers are given the next sequential number from the last section recovered.
	curated_length	The length of the section core material, in meters. This may be different than the liner length for the same section. Hard rock cores will often have spacers added to prevent rock pieces from damaging each other.
	liner_length	The original length of core material in the section, in meters. Sum of liner lengths of all the sections of a core equals core recovery.
	core_catcher_stored_in	Sometimes the core catcher is stored in a D tube with a section. core_catcher_stored_in contains the section number of the D tube that holds the core catcher.
	section_comments	Comments about this section

Sample	sample_id	Oracle-generated sequence number that with location uniquely identifies a sample.
	location	Code that indicates which Janus application assigned the sample_id. Values are SHI (ship), GCR (Gulf Coast Repository), ECR (East Coast Repository, WCR (West Coast Repository) and BCR (Bremen Core Repository). Used with sample_id to uniquely identify a sample.
	s_c_leg	Number identifying the cruise for which data were entered into the database. Foreign key used with s_c_sampling_code to link samples with a scientist's sample request.
	s_c_sampling_code	Code used to identify samples taken for a sample request. Used with s_c_leg.
	sam_archive_working	Part of section where sample was taken. Valid values: WR – whole round, A – archive half, W – working half.
	top_interval	Distance in meters from the top of the section to the top of the sample.
	bottom_interval	Distance in meters from the top of the section to the bottom of the sample.
	piece	Additional identifier for hard rock samples. Each individual piece of rock within a section is numbered consecutively starting at the top of the section.
	sub_piece	Additional identifier for hard rock samples. When a piece is broken, the individual fragments are given consecutive letter designations. Note that subpiece assignments must be made in conjunction with piece numbers.
	beaker_id	The number on the moisture density beaker. Used for samples analyzed for moisture and density.

MOISTURE AND DENSITY - MAD		
Table Name	**Column Name**	**Column Comment**
	volume	Volume of sample.
	entered_by	Indicates who entered the sample into the database.
	sample_depth	Depth of the sample.
	sample_comment	Comment about the sample.
	sam_repository	Repository where sample was taken. Valid values SHIP (ship), GCR (Gulf Coast Repository), ECR (East Coast Repository), WCR (West Coast Repository) and BCR (Bremen Core Repository).
	sam_sample_code_lab	Code to indicate the shipboard lab that will perform the initial analysis.
	sam_section_id	Unique Oracle-generated sequence number to identify each section. This is a foreign key that links a sample to leg, site, hole, core, and section.
	timestamp	Date and time when sample was entered into database. Samples taken before November 25, 1998 and migrated samples have the timestamp 11/25/1998 12:26PM.

Appendix II. Description of data items from Moisture and Density query with Output Raw Data option

Item Name	Column Description	Format
Leg	Number identifying the cruise. The ODP started numbering the scientific cruises of the *JR* at Leg 101. A leg was nominally two months duration. During the 18+ years of the ODP, there were 110 cruises on the *JR*.	Integer 3
Site	Number identifying the site. A site is the location where one or more holes were drilled while the ship was positioned over a single acoustic beacon. The *JR* visited 656 unique sites during the course of the ODP. Some sites were visited multiple times, including some sites originally visited during the Deep Sea Drilling Program for a total of 673 site visits.	Integer 4
Hole	Letter identifying the hole. Multiple holes could be drilled at a single site by pulling the drill pipe above the seafloor, moving the ship some distance away and drilling another hole. The first hole was designated 'A' and additional holes proceeded alphabetically at a given site. Location information for the cruise was determined by hole latitude and longitude. During ODP, there were 1818 holes drilled or deepened.	Text 1
Core	Cores are numbered serially from the top of the hole downward. Cored intervals are up to 9.7 m long, the maximum length of the core barrel. Recovered material was placed at the top of the cored interval, even when recovery was less than 100%. More than 220 km of core were recovered by the ODP.	Integer 3
Coretype	All cores are tagged by a letter code that identifies the coring method used.	Text 1
Section	Cores are cut into 1.5 m sections in order to make them easier to handle. Sections are numbered serially, with Section 1 at the top of the core. MAD analyses were made on samples taken from the sections. Core Catcher sections identified as "CC."	Integer 2 or Text 2
Top (cm)	The top interval of a measurement in centimeters measured from the top of a section.	Decimal F4.1
Bottom (cm)	The location of the bottom of a sample in centimeters measured from the top of a section.	Decimal F4.1
Depth (mbsf)	Distance in meters from the seafloor to the sample location.	Decimal F7.3
Water Content (bulk) (%)	Water content, relative to bulk mass.	Decimal F5.1
Water Content (dry) (%)	Water content, relative to solid mass.	Decimal F5.1
Bulk Density (g/cc)	Mass per unit volume for the sample before drying.	Decimal F5.3
Dry Density (g/cc)	Mass per unit volume for the sample after drying.	Decimal F5.3
Grain Density (g/cc)	Ratio of mass to volume of the solids, after drying.	Decimal F5.3
Porosity (%)	Percentage of pore volume or void space; that volume within rock that can contain fluids.	Decimal F4.1
Void Ratio	The ratio of the volume of void space to the volume of the solids.	Decimal F5.3
Mass(bulk+beaker)(g)	Mass of the wet sample and beaker.	Decimal F6.3
Mass(dry+beaker)(g)	Mass of the dried sample and beaker.	Decimal F6.3
Vol.(bulk+beaker)(cc)	Volume of the wet sample and beaker	Decimal F6.3
stdev(Vol.(bulk+beaker))	Statistical value which measures how much deviation individual measurements are from the mean value.	Decimal F6.3
No of measurements (Vol(bulk+beaker))	Number of volume measurements made.	Integer 2
cell(Vol.(bulk+beaker)))	Number of the pycnometer cell in which the measurements were made.	Integer 1
Vol.(dry+beaker)(cc)	Volume of the dry sample and beaker.	Decimal F6.3
stdev(Vol.(dry+beaker))	Statistical value which measures how much deviation individual measurements are from the mean value.	Decimal F6.3
No of measurements (Vol.(dry+beaker))	Number of volume measurements made.	Integer 2

Item Name	Column Description	Format
cell(Vol.(dry+beaker))	Number of the pycnometer cell in which the measurements were made.	Integer 1
Date/Time	Date and time of sample analysis.	Text 16 (yyyy-mm-dd hh:mm)
Beaker	Number of the beaker in which a sample was analyzed	Text 10
Mass beaker (g)	Mass of the beaker in grams.	Decimal F6.3
Vol beaker (cc)	Volume of the beaker in cc.	Decimal F6.3
Mass wet (g)	Mass of the wet sample minus the beaker mass in grams.	Decimal F6.3
Mass dry (g)	Mass of the dry sample minus the beaker mass in grams.	Decimal F6.3
Mass of porewater (g)	Calculated mass of the porewater in grams.	Decimal F6.3
Mass of Solids (salt corrected) (g)	Calculated mass of the solid material minus salt in grams.	Decimal F6.3
Vol of Porewater (cc)	Calculated volume of the pore water in cc.r	Decimal F6.3
Mass of Evap. Salt (g)	Calculated mass of salt in grams.	Decimal F6.3
Vol. of Evap. Salt (cc)	Calculated volume of salt in ccc.	Decimal F6.3
Vol. Bulk (cc)	Measured volume of the wet sample minus the beaker volume in cc.	Decimal F6.3
Vol. Solids (cc)	Calculated volume of the dry sample minus the volume of salt, in cc.	Decimal F6.3
Vol. Dry (cc)	Measured volume of the dry sample minus the beaker volume in cc.	Decimal F6.3
Method	Method used to calculate MAD properties	Text 2
Comments	Comments	Text 80